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IV. *On the difference of Longitude between the Observatories of Armagh and Dublin, determined by Rocket Signals. By the* Rev. T. R. Robinson, D.D., *Member of the Royal Irish Academy, and other Philosophical Societies.*

Read 24th June, 1839.

IN the communication respecting the Chronometric Longitudes of Armagh and Dublin, which I had the honor of submitting to the Academy last winter, I mentioned that it was our intention to determine the difference of our meridians by rocket signals; this has since been performed, and has given results which are the subject of this paper.

The method of signals is the most obvious of all, and under favourable circumstances, the most accurate. In it, the time of one place is transported to another, not by any machine, imperfect in its performance, and disturbed by that very transporting; the chronometer in it is light. If the appearance used for a signal be instantaneous, the only known source of error is in the determination of the Observatory time, which equally affects all other longitude methods. It appears to have been first used by the celebrated Picart, in a journey to Denmark, for the purpose of ascertaining the true position of Tycho's Observatory. He caused a fire to be kindled on the tower of the Observatory of Copenhagen, which was occasionally covered by a screen, and the time of its disappearance noted there, as well as by an observer at the ruins of Uraniburg. The distance is not more than seventeen miles, and there must have been some difficulty in covering the fire rapidly, as, from a passage in another of Picart's works, it appears to have been three feet in diameter. If, instead of a fire, one of Drummond's lights, placed in the focus of two Fresnel's lenses, directed to the stations, were suddenly covered by a hood, we should have a signal visible at any distance; which, besides being perfect in its nature, might serve to remove a doubt which has sometimes occurred to me. The impression of a

luminous object remains for one or two-tenths of a second on the eye: is this duration the same for all persons? Is there a corresponding delay in the perception of light at its first appearance; or, does the mind take instantaneous cognizance of the action on the retina? If not, is the interval of time required the same for every observer? The beautiful experiments of Mr. Wheatstone* show that we can see an object whose visibility lasts only the millionth part of a second; but our perception of it may not be synchronous with its appearance. All of this which concerns the astronomer might be decided by observing the reappearance of the light, as well as its vanishing. The management of chemical apparatus on a mountain summit is, however, no easy matter, and Lieut. Larcom, R. E., has suggested an application of the heliostat, which offers the same results: directing its beam to one station, but diverting a portion to the other by a second mirror, suitably placed, the same occultation and reappearance may be effected with the utmost facility. The necessary apparatus was ready, and if there had been enough of sunshine in May, I should have reported on the performance of it; but I hope that before these longitude operations are completed, I shall have another opportunity.

No more mention of fire signals occurs in the annals of astronomy till 1735, when De La Condamine proposed to measure an arc of longitude by means of the flash of cannon; taking the idea, in all probability, from the ridiculous project of Whiston. As the signals are generally given on mountains, where cannon are of difficult conveyance, his proposal is scarcely less absurd; but it was made practicable four years after by Cassini and Lacaille, who used the powder without the artillery. Stationed on mountains, in the south of France, 110 miles apart, these astronomers observed the flash of ten pounds of powder fired at an intermediate point, and deduced, though but imperfectly, the difference of longitude. Besides the imperfection of their means of getting the time, the quantity of powder used was excessive, and its flame must have lasted one or two seconds. Even with so small a quantity as half a pound, this inconvenience is felt: Professor Santini complains that the signals given with this quantity, at Monte Baldo, in 1824, were not instantaneous, the inflammation lasting $\frac{1}{3}$ of a second. It must, however, be observed, that this is more remarkable when the powder is unconfined, than when fired in ordnance, or in the head of a rocket.

* Philosophical Transactions, 1834, p. 591.

Nor is such a quantity as ten pounds at all necessary in respect of visibility. Von Zach found that even so little as four ounces was seen at 150 miles, by the reflection of its light from the air, the flash itself being below the horizon; and that it was visible at 140 in the twilight:* and the French observers† state, that at twenty-seven miles one-eighth of an ounce can be seen with the naked eye. These are important as guiding facts; at the same time, the superior clearness of the air in the central parts of Germany should be kept in mind.

This method was again forgotten till Von Zach revived it at the beginning of this century. It has since been extensively used in Germany,‡ and by the French and Italian astronomers in the measurement of an arc of longitude between Marennes and Fiume.§ Where the localities of the line afford fit stations, this method is very satisfactory; but, where mountains of the requisite height, and in proper places, are wanting, a sufficient elevation must be obtained by art. I am not prepared to say how far it might be possible to obtain this by "Captive balloons," though the fates of Pilatre de Rozier and Madame Blanchard are strong arguments against the union of ærostation and pyrotechny.‖ The use of rockets in such cases was proposed by Robins, in 1749, and was practised by the elder Wollaston, and some other astronomers, near London, in 1775. More lately it was used on a large scale by the French, between Brest and Strasbourg, and by a commission of French and English, between Greenwich and Paris. The first is briefly described in the elegant notice by Major Sabine, given in the Quarterly Journal, vol. xxiii.; and that part which was done in 1824 is given with sufficient detail in the Memorial du Depot de la Guerre, vol. iii., to enable us to appreciate its value. It seems to have been unsuccessful, as out of 300 signals, on each branch of the arc, only six transmissions in the first attempt occurred on one branch, and none in the other; and on the second trial, out of 360, only thirty-six on the first. It is possible that this may

* Correspondence Astronomique, vol. iii., p. 437.

† Nicollet Con. des Tems, 1829, p. 381.

‡ For details of some of these by Littrow, see Cor. Astron., vol. vii. p. 257.

§ Con. des Tems, and Plana, Arc du Parallele Moyen.

‖ Howitzer shells were tried by the French, but rejected, as the flash was not sufficiently bright; their fragments would, I think, be very dangerous to those who give the signals, and the howitzer not easily managed on a mountain.

have been owing to the bad quality of the rockets employed, as they are said to be similar to those furnished for the English operation, which proved defective, a large proportion of them bursting. They were, in fact, overloaded, the signals being given with eight ounces of powder; and it seems that in attempting to make them able to carry this to the requisite elevation, the limit of strength was approached rather too closely. None of the distances are excessive. That (La Heve, St. Clair) which in the first line barred all transmission, is but seventy-one statute miles; it however required an elevation of 680 yards, which probably many of the rockets did not reach. Colonel Bonne, who reports this, attributes the failure to the fog which rests on the Seine, as the line of sight crossed this river seven times; and seems to think that in all such operations, the passing large surfaces of water should be avoided. Before adopting this conclusion, we should remember that in 1825, when the line was changed, and when no distance exceeded fifty-two miles, no greater success was obtained. Perhaps sufficient attention was not paid to the selection of clear nights for the signals; as every astronomer is aware that sometimes small stars can be seen almost to the horizon, while in ordinary good observing weather, this is by no means the case. *When such favourable circumstances are noticed at the observatories*, which are the extremities of the chain, a transmission of signals by numerous intermediate posts, should run along the line as a notice to fire the rockets, and thus success may be insured by a moderate expenditure of blue lights and patience.

The operations on the arc between Greenwich and Paris are described by Sir John Herschel in the Philosophical Transactions for 1826, with his usual precision and elegance: the memoir explains the method of successive signals with peculiar clearness, and in particular illustrates the method of using the broken sets to the best advantage. The distances here also were moderate, the greatest (La Canche, Lignieres) being only fifty-six miles; yet the success was not very great, ten complete transmissions being obtained only on four nights out of twelve, by 120 signals at each of the three stations. It is however evident, that Colonel Bonne's opinion of the difficulty of passing water does not hold with respect to sea; for, while 109 of the Wrotham signals were seen at 26 miles, ninety-two of those at La Canche, at fifty-two miles, were visible.

These operations were not followed up in Great Britain for several years,

but in 1834 the British Association expressed a wish that the longitudes of Cambridge, Oxford, Edinburgh, Dublin and Armagh should be determined by the method of signals, and by chronometers. For this object it appointed a committee from its astronomical members, and gave them authority to apply to Government for any assistance that might be necessary. Of this Sir William Hamilton and myself are members; and I am happy to say that its work has commenced in Ireland. As far as the chronometric part is concerned, there is, perhaps nothing to be desired, except the personal equation of the Greenwich observers, which will be determined when an opportunity offers; and though the signal-measure, which is the subject of the present communication, relates to the smallest of the arcs, it is important, both on its own account, and as a means of training us for more extensive lines.

The Observatories of Armagh and Dublin are situated very unfavourably for the signal-method, there being no point visible from both. About four miles south of the first, a range of hills rises from 600 to 1000 feet above its level; but these are shut out from the view of Dublin, by a ridge about twelve miles to the north of it, 500 feet high. Even with powerful rockets it was not easy to clear these barriers; but our difficulties were removed by the aid, and, I may add, encouragement which we received from our friend Lieutenant Larcom. He not only gave us whatever information we required, but added a personal attention to the details of our work, without which it would, perhaps, have failed. Among other matters for which we have to thank him, was a diagram, in which he laid down the observatories, and all the mountains which could possibly serve as signal stations. To each was annexed its height, distance, azimuth at each observatory, altitude affected by the average terrestrial refraction; and when the line of sight was thrown up by an intervening ridge, the height there, and the elevation at which it passed the summit of the station, and which, of course, it was necessary that the rocket should clear, after allowing for refraction.* This

* It is really wonderful how completely every undulation of the ground has been registered in the Survey. The altitudes sent to me, which must have been computed from the general sections, agree with observation in the most extraordinary way. A fact of another kind will show such members as may not be acquainted with these things the precision of the Ordnance Survey. I set a telescope to the azimuth given for Slieve Gullion, and ascended the intervening hill with a theodolite, which I moved till, by signal from the Observatory, it was in the line; then I took, with

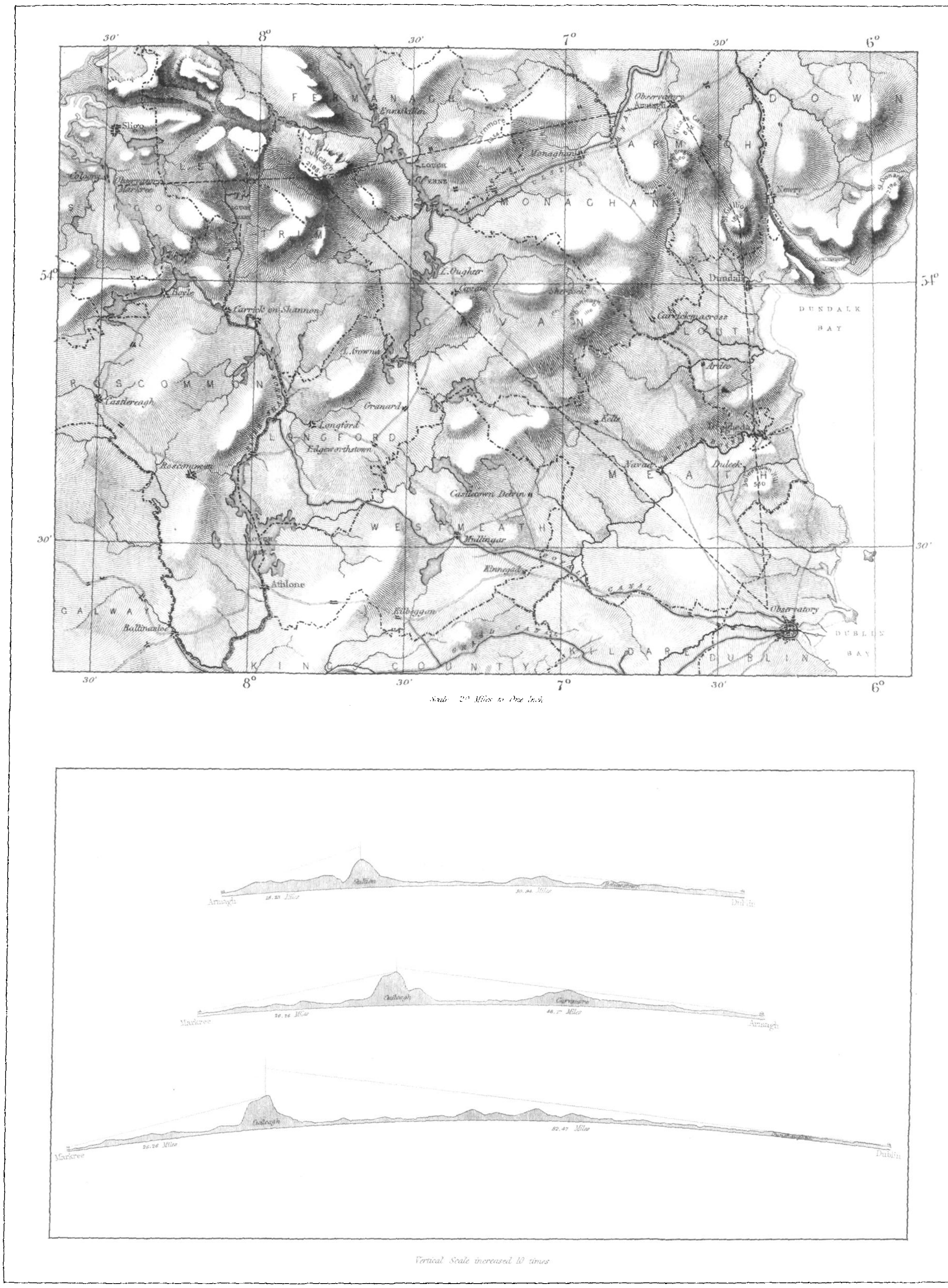
showed at once that our choice lay between two—Loughanleagh, in the county of Cavan, and Slieve Gullion, at the southern extremity of Armagh. The first would divide the distance better, but as its line passes through the smoke of the town of Armagh, the other was adopted.

Its summit, 1893 feet above the sea, is occasionally visible at Dublin, but is 800 feet below my view, the distances being 50.9 and 18.2 miles, as shewn in the annexed map, for which I am obliged to Lieutenant Larcom; the section beneath shows the character of the intervening land. From this, the necessary size of rockets can be inferred; the pound rocket ($1^{\text{in.}}7$ diameter) rises 1400 feet, on an average, but cannot carry four ounces of powder, while it is evident from Sir J. Herschel's paper, that the two-pounder ($2^{\text{in.}}1$ diameter) is quite sufficient. These projectiles, when of such a size, require extreme care in the details of manufacture; and, if ill made, are not merely uncertain, but actually dangerous; and the case seeming of sufficient importance to authorize an application to Government, I made an application to the Board of Ordnance, stating the nature of my work, and requesting a supply of rockets. My reliance on that liberality which I have always found in the Government, when the importance of any scientific object is duly laid before them, was not disappointed, and I have much pleasure in acknowledging the kindness with which the Master-General, Sir Hussey Vivian, and the other members of the Board attended to me; not merely giving the rockets, but tents for the firing party, and other matters which were necessary, but which I had in the first instance overlooked.* I may add, that as a measure of precaution against the interference of curious visitors, two of the police were placed at my disposal; it was, however, unnecessary, as, though great crowds of the peasantry were attracted by an exhibition so new to them, they shewed every disposition to oblige and assist.

Having made all requisite preparations, I proceeded, on the 13th of May, to

the theodolite, the angle between the telescope and the pile on the mountain top, where our rockets were to be fired; it proved 180°. 0′. 0″., or the three points were in one right line.

* The rockets were remarkably good; *not one* burst, which certainly is a singular contrast to the French rockets in Sir J. Herschel's and Colonel Bonne's operations. Their average rise, on the only evening that I measured it, was 800 yards; they had, however, only four ounces of powder, but the part of the case which contained it weighed six ounces more, so that they actually carried a greater weight than the French.



MAP AND SECTIONS

SHEWING THE RELATIVE POSITIONS OF THE OBSERVATORIES OF

DUBLIN, ARMAGH AND MARKREE.

1840

establish my party at the mountain. This month was found by the officers of the Survey favourable for their work, and I knew it to be equally so for astronomical observations. On arriving, I found all difficulty removed by the kindness of Dr. Campbell, the rector of Forkhill, who had, with the hospitality for which he is remarkable, even in Ireland, provided such assistance that we were able to have the tents pitched, and the stores arranged within a couple of hours; nor was his attention bounded with this, but continued during the whole of our operations.*

The wind blew furiously from the N.W., and next day the snow fell several inches deep on the mountain. I had not reckoned on such weather, but the sky was clear at intervals; and I knew that even a gale will not affect the ascent of a well proportioned rocket. I therefore left my eldest son, Mr. T. A. Robinson, in command of the party, with directions to commence firing at ten, and give a signal every five minutes, as far as twenty, unless the night was decidedly cloudy. It would have been better to have arranged signals with him, but in my uncertainty of the quality of the rockets, I was desirous to economize them as much as possible.

Sir W. Hamilton (H) and myself (R) had arranged a list of stars to be observed daily, and, as I have stated, Lieutenant Larcom had given us the means of directing our instruments to the mountain with astronomical precision. The signals were, in fact, visible at Dublin, when the weather was fine, by the naked eye, but this could not be trusted to in moonlight or cloud, and they were observed there with Sharp's equatorial, whose telescope, by Cauchoix, has an object glass of flint-glass and quartz, $5^{\text{in}}.2$ aperture, with a power of 54. The time was noted by Arnold's clock. At Armagh the locality permitted the use of more instruments. My assistant, Mr. Edmondson (E), observed, by the transit clock, with a $3\frac{1}{2}$ feet achromatic, by Tulley, of $3^{\text{in}}.2$ aperture, power 30, placed at the

* The tents were pitched at the cairn, which is the trigonometrical point of the Survey. It is of great size, and contains a sepulchral chamber, in the form of a cross. The peasantry open it with great reluctance, and close it as soon as possible, believing it the dwelling of a sorceress, one of whose feats is given in Miss Brooke's Relics of Irish Poetry. Afterwards, when the weather became still more tempestuous, they were moved about 600 yards northward, near the lake which is found on this lofty summit. This new position is about 100 feet lower, but the rockets were much too powerful to make this of any consequence; they might in fact have been fired in the valley of Forkhill, had I been aware of their excellence.

southern window of the transit room. I had intended to use my great reflector, with a power of 70, but the rapid motion of the rockets across the field* of view, and the oblique movements of the equatorial, $2^h. 15^m.$ from the meridian embarrassed me, and after losing a few, I betook myself to its finder, $2\frac{3}{4}^{in}$ aperture, power 18, with a field of $1\frac{1}{2}$ degrees, which proved quite satisfactory. The clock is by Sharp, with a mercurial pendulum. Mr. Robert Finlay (F) was to observe with Troughton's equatorial, $2\frac{3}{4}^{in}$ aperture, power 75, but as the field of view is narrow, and from not being accustomed to such instruments, he was even more embarrassed than I; he also was driven to the finder, which is a common affair, with an aperture of an inch. The clock has a gridiron pendulum.

The equatorial clocks were compared with the transit clock by chronometers, before and after the observations of each night; and as the simple reduction of these indications to sidereal time is not likely to involve any mistake, the observations are given in sidereal time, as it seems needless to occupy valuable space by setting down the actual clock times noted. They are as follow:

May 14, 1839, cloudy, high wind, fourteen rockets fired.

		ARMAGH.	DUBLIN.
No. 1.	R, E	Seen, but not observed.	. . . .
No. 2.	R, E	Seen.	. . . .
No. 3.	R	Seen.	
	E	$13^h. 36^m. 24^s. 68$	H $13^h. 37^m. 39^s. 10$
		E observed with the naked eye.	
No. 4.	R, E	Seen.	H . $42^m. 32^s. 10$
No. 5.	R, E	Ditto.	H . 48 25 10

* They rose, on an average, a degree of declination above the boundary of view, while the field is but 38 minutes.

	ARMAGH.					DUBLIN.				
No. 6.	R / E	13h.	51m.	51s.	45	H	13h.	53m.	5s.	30
No. 7.	R / E	.	56	46	75	H	.	58	0	10
No. 8.	R / E	14	1	51	74	H	14	3	6	10
No. 9.	R / E	.	6	28	74	H	.	7	44	00
No. 10.	R / E	.	11	28	24	H	.	12	43	10
No. 11.	R	.	16	18	43	H	.	17	33	10
	E	.	.	18	67					

Marked doubtful at Dublin.

No. 12.	R	.	21	34	23	H	.	22	49	10
	E	.	.	34	67					
No. 13.	R / E	Lost in cloud,				H	.	28	51	10

Doubtful at Dublin.

No. 14.	R	14	31	56	23	H	14	33	10	60
	E	.	.	56	66					

The flash, at lighting the rockets, was seen at Dublin; the train, as well as the explosion, (which was instantaneous,) was visible by the naked eye at Armagh.

On May 16th, thirteen rockets were fired, but the evening became rainy, and many were missed.

		ARMAGH.				DUBLIN.
No. 1.	R	$13^h.$	$35^m.$	$31^s.$	80	
	E	.	.	31	67	. . . . . H $13^h.$ $36^m.$ $46^s.$ 62
	F					
No. 2.	R	.	40	48	30	
	E	.	.	47	67	. . . . . H . 42 2 12
	F	.	.	47	33	
No. 3.	R	.	45	41	79	
	E	.	.	46	67	. . . . . H . . . .
	F					

R noted the disappearance of the train in the cloud, which was sudden. E suspected the explosion. H saw train but not explosion, and did not note the time of disappearance, which, however, may sometimes give a good result.

No. 4.	R	. $50^m.$	$40^s.$	89	
	E	. .	40	67	. . . . . H . . . .
	F	. .	42	23	

The rocket turned before exploding, and was not seen in Dublin.

No. 5.	R	. $55^m.$	$57^s.$	79	
	E	. .	57	67	. . . . . H . . .
	F	. .	57	43	

Faint, not seen in Dublin.

No. 6.	R	$14^h.$	$1^m.$	$14^s.$	08	
	E	.	.	13	66	. . . .
	F	.	.	13	39	
No. 7.	R	.	5	45	78	
	E	.	.	45	65	. . . .
	F	.	.	45	99	
No. 8.	R					
	E	.	10	48	56	. . . .
	F					

	ARMAGH.				DUBLIN.			
No. 9.	R Lost in cloud.							
	E . 15^m. 44^s. 66				. . . .			
	F							

No. 10. Lost in heavy rain, though it was clear at the mountain.

No. 11.	R .	25^m.	55^s.	75				
	E . .		55	66	. . . . T .	27^m.	10^s.	12
	F . .		55	48				

Observed at Dublin by Mr. Thompson, Sir Wm. Hamilton's assistant.

No. 12.	R .	30^m.	39^s.	75				
	E . .		39	36	. . . . T .	31^m.	54^s.	12
	F . .		39	28				
No. 13.	R .	35	23	94				
	E . .		23	55	. . . . H .	36	38	12
	F . .		23	22				

The rocket-stand was moved, as the fury of the gale made it impossible to remain at the cairn, and all work was impracticable till the 20th, when it was fine on the mountain, but there was much haze below, strongly illuminated by the moon; and some annoyance from flying clouds. Twenty rockets were fired.

No. 1.	R	13^h. 52^m.	38^s.	79					
	E . .		38	63	. . . . T	13^h.	53^m.	53^s.	70
	F . .		39	18					

Faint at Armagh.

No. 2.	R .	57^m.	43^s.	79					
	E . .		43	63	. . . . T .		58	58	32
	F . .		44	18					
No. 3.	R	14^h. 2^m.	14^s.	92					
	E . .		15	16	. . . . T	14	3	29	82
	F								

No. 4. R and T saw train but not explosion.

	ARMAGH.				DUBLIN.
No. 5.	Train seen, but not flash,				T . 13^m. 37^s. 70
No. 6.	R .	17^m.	36^s.	96	T Train, but not flash.
	E				
	F .	.	37	22	
No. 7.	R .	22	24	13	T Not seen.
	E .	.	23	77	
	F .	.	24	22	
No. 8.	R .	27	19	53	T Train, but not flash.
	E .	.	19	27	
	F .	.	19	22	
No. 9.	Train seen, but not flash,				T . 33^m. 29^s. 70
No. 10.	R .	36^m.	55^s.	73	T . 38 10 10
	E .	.	55	77	
	F .	.	55	71	
No. 11.	R .	42	1	93	T . 43 17 70
	E .	.	6	78	
	F				

R noted the disappearance in the cloud. T appears to have taken the same. E was a suspicion. R used the large reflector for the next three.

No. 12.	R .	47^m.	9^s.	13	T . 48^m. 23^s. 70
			9	08	
			9	20	
No. 13.	R .	52	9	03	T . 53 23 70
	E .	.	9	48	
	F .	.	9	20	

Barking of dogs troublesome at Armagh.

No. 14.	R .	57^m.	25^s.	13	T . 58 39 70
	E .	.	24	78	
	F .	.	25	20	

	ARMAGH.						DUBLIN.				
No. 15.	R	15^h.	2^m.	17^s.	93		T	15^h.	3^m.	31^s.	70
	E	.	.	17	78						
	F	.	.	18	19						
No. 16.	R	.	7	24	43		T	.	8	38	70
	E	.	.	24	68						
	F	.	.	24	69						
No. 17.	R	.	12	22	63		T	.	13	36	70
	E	.	.	22	78						
	F	.	.	22	99						
No. 18.	R	.	17	41	91		T	.	18	55	70
	E	.	.	41	28						
	F	.	.	41	69						

This did not rise into the field of R's telescope, but was noted as above by another person at the same clock, with the naked eye.

No. 19.	R	.	22^m.	17^s.	84		T	.	23^m.	31^s.	70
	E	.	.	17	68						
	F	.	.	18	07						
No. 20.	R	15	27	16	93		T	15	28	31	20
	E	.	.	16	79						
	F	.	.	17	17						

On the 21st, twenty rockets were fired.

No. 1.	Not seen.						T	13^h.	57^m.	35^s.	38
No. 2.	R	14^h.	1^m.	35^s.	87		T	14	2	50	38
	E	.	.	35	73						
	F	.	.	35	62						
No. 3.	R	.	6	15	87		T	.	7	30	38
	E	.	.	16	23						
	F	.	.	16	02						

	ARMAGH.				DUBLIN.			
No. 4.	R	11^{m}.	25^{s}.	36	T	12^{m}.	39^{s}.	38
	E		25	73				
	F		25	61				
No. 5.	Not seen.				T	17	59	88
No. 6.	Not seen.				H	22	37	38

H notes that it seemed to last from 36^{s}. to 38^{s}.; it was probably the train seen through an opening in the cloud.

No. 7.	Not seen.				T	27^{m}.	54^{s}.	38
No. 8.	R	31^{m}.	39^{s}.	82	T Saw train but no flash.			
	E							
	F							
No. 9.	R	36	33	83	H	37^{m}.	48^{s}.	38
	E		34	23				
	F		34	71				
No. 10.	R	41	41	03	H	42	55	38
	E		41	13				
	F		40	71				
No. 11.	R	47	0	33	H	48	14	38
	E		0	14				
	F		0	77				

R noted this as low. F lost it for a time, but saw the flash.

No. 12.	R	51^{m}.	45^{s}.	23	H	52	59	88
	E		45	44				
	F		45	67				
No. 13.	R	56	41	02	H	57	55	38
	E		41	04				
	F		40	76				

No. 14. Exploded before it rose to its full height and was not visible at Armagh.

		ARMAGH.		DUBLIN.
No. 15.	R	15^h. 6^m. 51^s. 02	T	15^h. 8^m. 5^s. 38
	E	. . 51 24		
	F	. . 51 76		

This also exploded at less than the usual elevation.

No. 16.	R	. 11^m. 52^s. 72	H	. 13 7 38
	E	. . 52 75		
	F	. . 52 76		
No. 17.	R	. 17 21 61	T	. 18 35 88
	E	. . 22 25		
	F	. . 22 24		

At Armagh the rocket disappeared in cloud, but passed through it, and the train and explosion were well seen.

No. 18.	R	. 21^m. 53^s. 81	T	. 23^m. 7^s. 38
	E	. . 53 65	H	. . 8 38
	F	. . 53 74		

H observed with a night-glass, held in the hand, but is unquestionably right.

No. 19.	R	. 26^m. 43^s. 29	H	. 27^m. 58^s. 38
	E	. . 43 25		
	F	. . 43 73		
No. 20.	R	. 31 44 49	H	. 31 59 08
	E	. . 44 45		
	F	. . 44 73		

In consequence of the miscarriage of a letter, there was no firing on the 22nd, the only perfectly fine night of the whole period; and though nine were fired on the 23rd, of which six were seen here, none were visible at Dublin. The moon was now so nearly full, and so low, that it became difficult to see the rockets at Armagh: and the results already obtained proved so satisfactory, that it was thought needless to repeat the signals from this station. Indeed, bad as the weather was, it was as favourable as that which has succeeded it.

As the most important part of longitude measures is the determination of the Observatory time, I annex the transit observations, and the clock corrections deduced from them.

The instrument at Armagh is $5\frac{1}{4}$ feet focal length, and 3.8 inches aperture, power 160; its axis was examined by the level daily, and its meridional position constantly verified by two marks, which being exactly adjusted to the meridian, would also detect any error of collimation, if it existed. This was insensible, as also is shown by six reversions made on May 25th, for the purpose of verifying the equality of the pivots, the difference of which is given by them $= 0^s.0004$, in fact, evanescent. At the same time their figure was tried by examining the inclination at every twenty degrees from the northern to the southern horizon; but though tenths of seconds of space can be estimated on the level, no error could be found. The transits were, except in two instances, taken by Mr. Edmondson.

At Dublin, they were taken by Mr. Thompson: the instrument has six feet focal length, and four inches aperture, power = 100. The inclination of its axis was found by the level, on the 8th, 17th, 22nd, and 23rd, $= +2''.18$; its meridional position by nine observations of Polaris, from April 30 to May 22, and its error of collimation by four of the same star, on May 20th, reversing between the wires, from which it appears that the observed transits require the correction,

$$-0^s.5371 + 0^s.6134 \text{ tang } \delta - 0^s.1059 \text{ secant } \delta.$$

The clock corrections are deduced from the places of Encke's Jahrbuch, which for γ Ursæ, and some other stars, agree better with our observations than those of the Nautical Almanac.

DUBLIN.					ARMAGH.			
DATE.	STAR.	OBSERVED TRANSIT.	NO. WIRES.	CLOCK CORRECTIONS.	STAR.	OBSERVED TRANSIT.	NO. WIRES.	CLOCK CORRECTIONS.
May 12. ⊙					Sirius,	6^{h}. 38^{m}. 5^{s}. 26	9	-2^{s} 19
					Procyon R,	7 30 54 72	9	−2 02
					Pollux R,	7 35 30 14	9	−2 21
					α Hydræ,	9 19 43 40	9	−2 03
					Regulus,	9 59 50 81	9	−1 99
					β Leonis,	11 40 54 36	9	−1 89
					γ Ursæ,	11 45 24 91	8	−1 79
					Polaris, S.P.	13 1 5 48	3	−1 25
					Spica,	13 16 47 13	9	−1 80
					Level	+ 1″ 45		
„ 13. ☽	β Leonis,	11^{h}. 40^{m}. 57^{s}. 34	5	-4^{s}.32	β Leonis,	11 40 54 06	9	−1 65
	Polaris, S.P.	13 1 27 00	1	−5 68	γ Ursæ,	11 45 24 52	9	−1 50
	Spica,	13 16 50 32	5	−4 19	Polaris, S.P.	13 1 6 90	3	−0 96
	η Ursæ,	13 41 18 91	5	−4 20	Spica,	13 16 46 61	9	−1 31
					Level	+ 1″ 45 lowered axis.		
„ 14. ♂	γ Ursæ,	11 45 27 10	5	−3 99	Procyon,	7 30 53 97	9	−1 23
					Pollux,	7 35 29 33	9	−1 36
					Regulus,	9 59 50 26	9	−1 40
					Level	+ 0″ 50		
„ 15. ☿	Rigel,	5 6 53 15	3	−4 38	Capella,	5 4 49 60	7	−1 53
	α Hydræ,	9 19 46 60	5	−4 50	Rigel,	5 6 49 58	3	−1 58
	Regulus,	9 59 53 94	5	−4 58	Sirius,	6 38 4 63	6	−1 58
					Pollux,	7 35 29 56	3	−1 63
					Level	+ 0″ 85		
„ 16. ♃	β Leonis,	11 40 57 76	5	−4 77	Procyon,	7 30 54 02	9	−1 29
	γ Ursæ,	11 45 27 72	5	−4 62	Pollux,	7 35 29 39	3	−1 43
					Regulus,	9 59 50 28	2	−1 43
					β Leonis,	11 40 53 94	9	−1 44
					γ Ursæ,	11 45 24 54	8	−1 34
					Level	+ 0″ 22		
„ 17. ♀	Polaris, S.P.	13 1 27 00	1	−3 15				
	Spica,	13 16 50 86	5	−4 76				
„ 19. ⊙					Regulus,	9 59 49 73	9	−0 90
					β Leonis,	11 40 53 32	7	−0 84
					γ Ursæ,	11 45 23 83	6	−0 65
					Spica,	13 16 46 22	9	−0 87
					Level	− 0″ 12		

DUBLIN.					ARMAGH.			
DATE.	STAR.	OBSERVED TRANSITS.	NO. WIRES.	CLOCK CORRECTIONS.	STAR.	OBSERVED TRANSIT.	NO. WIRES.	CLOCK CORRECTIONS.
May 20.	Capella,	5h. 4m. 53s. 39	5	−5s.17	Capella,	5h. 4m. 48s. 50	9	−0s.35
☽	Rigel,	5 6 53 93	4	−5 16	Sirius,	6 38 3 52	9	−0 49
	Procyon,	7 30 58 52	5	−5 24	Procyon,	7 30 53 01	9	−0 31
	Pollux,	7 35 33 61	4	−5 35	Regulus,	9 59 49 16	8	−0 36
	β Leonis,	11 40 58 24	5	−5 29	β Leonis,	11 40 52 74	4	−0 28
	γ Ursæ,	11 45 28 02	4	−5 05	γ Ursæ,	11 45 23 33	8	−0 21
	Polaris, s.p.	13 1 29 50	2	−4 08	} Spica,	13 16 45 59	9	−0 24
	reversed,	. . 37 33	2	−5 08				
	α Serpentis,	15 36 28 86	5	−5 19	Level	+ 0″ 15		
„ 21.					Sirius,	6 38 3 15	3	−0 14
♂	α Coronæ,	15 28 0 46	5	−5 09	Spica,	13 16 45 15	9	+0 19
	α Serpentis	15 36 28 84	5	−5 16	η Ursæ,	13 41 14 40	9	+0 25
					Level	+ 0″ 42		
„ 22.	Capella,	5 4 53 17	5	−4 94	Capella,	5 4 47 72	6	+0 46
☿	Rigel,	5 6 53 80	2	−5 03	Rigel,	5 6 47 52	3	+0 52
	β Tauri,	5 16 12 63	2	−5 11	β Tauri,	5 16 6 80	9	+0 35
	Sirius,	6 38 8 98	5	−5 12	Sirius,	6 38 2 67	9	+0 27
	Procyon,	7 30 58 06	5	−4 79	Regulus,	9 59 48 26	9	+0 53
	Pollux,	7 35 33 36	5	−5 12	β Leonis,	11 40 51 75	3	+0 70
	Regulus,	9 59 54 28	5	−4 99	γ Ursæ,	11 45 22 42	8	+0 69
	Polaris, s.p.	13 1 33 10	3	−6 57	Spica,	13 16 44 67	8	+0 68
					η Ursæ,	13 41 13 83	8	+0 87
					Level	+ 0″ 44		

Hence I deduce the clock corrections:

May 14,	Dublin,	= − 4s. 25	at	11h.	56m.
	Armagh,	= − 1 34	„	15	0
„ 16,	Dublin,	= − 4 65	„	12	47
	Armagh,	= − 1 35	„	15	0
„ 20,	Dublin,	= − 5 22	„	13	22
	Armagh,	= − 0 20	„	15	50
„ 21,	Dublin,	= − 5 13	„	13	38
	Armagh,	= + 0 26	„	15	50

It will be observed that both clocks were accelerated at the 15^{th}; this was chiefly caused by a fall of the barometer of three-fourths of an inch (Memoirs Ast. Soc., vol. v. p. 125). The mercurial pendulum of my clock is accelerated $0^s.37$ by a fall of one inch; the coefficient for the gridiron pendulum which belongs to the Dublin clock is probably greater, but as the effect is only differential, it seemed unnecessary to allow for it.

The differences of longitude given by the signals are as follows:

DATE.	NO.	R.	E.	F.	MEAN.
May 14.	3	. . .	$1^m.14^s.42$		Mean of R (8) $1^m.14^s.45$
	6	$1^m.13^s.85$	. . .		E (4) . 14 30
	7	. 13 35	. . .		
	8	. 14 36	. . .		
	9	. 15 26	. . .		
	10	. 14 86	. . .		
	11	. 14 67	. 14 43		
	12	. 14 87	. 14 43		
	14	. 14 37	. 13 94		
„ 16.	1	1 14 82	1 14 95	. . .	Mean of R (5) 1 14 31
	2	. 13 82	. 14 45	$1^m.14^s.79$	E (5) . 14 64
	11	. 14 37	. 14 46	. 14 64	F (4) . 14 79
	12	. 14 37	. 14 76	. 14 84	
	13	. 14 18	. 14 57	. 14 90	
„ 20.	1	. 14 91	. 15 07	. 14 52	Mean of R (14) 1 14 45
	2	. 14 53	. 14 69	. 14 14	or omitting the two doubtful
	3	. 14 90	. 14 66	. . .	R′ (12) 1 14 40
	10	. 14 37	. 14 33	. 14 39	Mean of E (13) . 14 40
	11	. 15 77?	. . .	. . .	Mean of F (12) . 14 12
	12	. 14 57	. 14 62	. 14 50	
	13	. 14 67	. 14 22	. 14 50	
	14	. 14 57	. 14 92	. 14 50	
	15	. 13 77	. 13 92	. 13 51	
	16	. 14 27	. 14 02	. 14 01	
	17	. 14 07	. 13 92	. 13 71	
	18	. 13 79?	. 14 42	. 14 01	
	19	. 13 86	. 14 02	. 13 63	
	20	. 14 27	. 14 41	. 14 03	
„ 21.	2	. 14 51	. 14 65	. 14 76	Mean of R (14) 1 14 47
	3	. 14 51	. 14 15	. 14 36	Mean of E (14) . 14 41
	4	. 14 02	. 13 65	. 13 77	Mean of F (14) . 14 24
	9	. 14 55	. 14 15	. 13 67	
	10	. 14 35	. 14 25	. 14 67	

DATE.	NO.	R.	E.	F.	MEAN.
May 21.	11	1m. 14s. 05	1m. 14s. 24	1m. 13s. 61	
	12	14 65	. 14 44	. 14 21	
	13	. 14 36	. 14 34	. 14 62	
	15	. 14 36	. 14 14	. 13 62	
	16	. 14 66	. 14 63	. 14 62	
	17	. 14 27	. 13 63	. 13 64	
	18	. 14 57	. 14 73	. 14 64	
	19	. 15 09	. 15 13	. 14 65	
	20	. 14 59	. 14 63	. 14 35	

Were we to suppose the results of each night of equal weight, and take the arithmetical mean, we should find,

$$\begin{aligned} R &= 1^m.\ 14^s.\ 44 \\ E &= \ .\ 14\ \ 44 \\ F &= \ .\ 14\ \ 38 \end{aligned}$$

but this condition cannot be assumed; for a greater number of signals are observed on some nights, and the clock correction is concluded with unequal probability. The probable error of the difference of observed times is, denoting by ϵ that of the transit of a single star supposed the same at each observatory (as it is at Armagh and Dublin in fact), and by s the number of stars,

$$= \pm \epsilon \sqrt{\frac{1}{s} + \frac{1}{s'}}$$

If the number of rockets be r, and the probable error of the observation of one at both observatories be $\pm \epsilon m$, that of the mean of the night is $\pm \frac{\epsilon m}{\sqrt{r}}$, and therefore that of the night's result

$$(\epsilon) = \pm \epsilon \times \sqrt{\frac{1}{s} + \frac{1}{s'} + \frac{m^2}{r}}$$

By examining these results, I find $\epsilon = \pm\ 0^s.\ 065$ and $\epsilon m = \pm\ 0^s.\ 23$ for R and E, F being greater, and hence the probable weight of each night

$$\text{W} = \frac{1}{\frac{1}{s} + \frac{1}{s'} + \frac{12}{r}} \quad *$$

To apply this, the Dublin correction on the 14th is derived from one star, and the mean of three on the preceding, and two on the following day. I assume $s = 3$.

At Armagh $s' = 3$.

On the 16th, two stars, and the mean of three preceding and one following give $s = 3$; $s' = 5$.

On the 20th, $s = s' = 7$.

On the 21st, two and the mean of seven and seven give $s = 9$; at Armagh, four and the mean of seven and nine give $s' = 11$.

Hence, calling the decimals of the second of a result L, we have

May 14,	W = 0.46154	WL = 0.20769	R
	0.27273	0.08182	E
May 16,	0.34091	0.10568	R
	Same	0.21818	E
	0.22059	0.17426	F
May 20,	0.875 }	0.39375 }	R
	0.77778 }	0.31040 }	R′
	0.82727	0.33091	E
	0.61765	0.07412	F

* This expression of W shows, that with us the flash can be observed with about the same precision as the appulse of a star to a wire; but a more important deduction may be made respecting the method by successive signals. As each of these *adds* to the denominator of W a term $\frac{12}{r}$ their number diminishes it rapidly. Thus on the 20th, if, as in the Paris and Greenwich arc, we had employed two intermediate stations, it would have been but 0.37 of its actual value, even supposing the transmission perfect. I am therefore decidedly of opinion, that stations of transmission should be made absolute stations, when it is possible, by furnishing them with transit instruments: this guards against failure, and scarcely lessens the value of the result. Thus in the case supposed, W is 0.33, but it will be obvious that in Sir J. Herschel's operation, had this been done, instead of the ten complete results which he obtained, he would have got at least ninety.

May 21, . . 0.94414	. . . . . .	0.44375	R
Same,	. . . . . .	0.38710	E
0.74356	. . . . . .	0.17845	F

The final means are, therefore,

$$\text{R} = 1^{m}.\ 14^{s}.\ + \frac{1^{s}.15087}{2.62159} = 1^{m}.\ 14^{s}.\ 439$$

$$\text{R}' = 1 \quad 14 \quad + \frac{1.06752}{2.52437} = 1 \quad 14 \quad 423$$

$$\text{E} = 1 \quad 14 \quad + \frac{1.01801}{2.38505} = 1 \quad 14 \quad 427$$

$$\text{F} = 1 \quad 14 \quad + \frac{0.42683}{1.58180} = 1 \quad 14 \quad 270$$

The result F has obviously far less weight than the other two, which must be attributed not merely to Mr. Finlay's total want of practice in such observations, but also to the small optical power of his telescope. Though it differs but little from the others, I think it best to omit it, and consider the mean of R and E as the definitive result

$$1^{m}.\ 14^{s}.\ 425.$$

But had I used it and retained the two omitted on May 20th, this would be only 0^{s}. 03 less, and identical with the result given by Mr. Dent's chronometers.

These, however, require a correction for what is called the *Personal Equation* of the transit observers. It may appear strange that two practised observers should not observe the passage of a star over a spider's line at the same instant, but the fact is undoubted, and the difference is not of a decimal or two, but in the case of perhaps the first of European astronomers, it exceeds a second. The cause is unknown, but as from its being almost invariably independent of the declination, it appears not to originate in the eye, the probability is, that it is caused by some exercise of thought in associating the indications of the ear to those of the eye. In most cases it is constant for many years in the same individual ; in some, probably by carelessness, it goes on increasing.

The usual method of determining its amount is thus : the observer, E, ob-

serves the transit of a star at the first wires, and T at the remainder. Each wire is then reduced to the centre; this is repeated for many stars. If they agree, there is no personal equation; otherwise, it is their difference. Or they may observe entire transits alternately on one night, and again inversely on a subsequent one, each taking the stars which the other had previously examined. The clock rates deduced from these will be ultimately too great, and too little, by the personal equation, which, therefore, is half their difference. Or, lastly, by a method shown to me many years since by Sir James South, which I prefer, as enabling the astronomer to decide several questions connected with the subject.* This requires an equatorial, whose micrometer wires are to be separated any quantity, I^s, and set parallel to the meridian. Let P, the personal equation, be the correction to be added to E, the time observed by one, to reduce it to T, that by the other; then

$$T^s - E^s - P^s = I^s \times \text{secant } \delta;$$

then move the equatorial, by its horary movement, into another position, and repeat the process till a sufficient number be obtained; then let the order of observing be inverted, and we have

$$E'^s + P^s - T'^s = I^s \times \text{secant } \delta;$$

and hence we find

$$2P^s = S\,(T^s - E^s) - S\,(E'^s - T'^s).$$

If the equatorial were very much out of adjustment, and the hour angle considerable, this process might require a correction, which, however, presents no difficulty. Far from the meridian a correction for refraction might also be required, but such circumstances will always be avoided.

I sent Mr. Edmondson to Dublin for the purpose of making such a comparison, which, after much delay by rainy weather, he effected on August 18th. Sharp's equatorial was used for the observations.

* In particular as to the moon. In many cases, I believe, the personal equation for this planet is different from that for stars; and that even for the first and second limbs it is not always equal. The bearing of this on the longitude method, by moon culminating stars, is evident, as also the mode of ascertaining its influence and amount.

With 71 Aquilæ, $\delta = -1^\circ\ 40'$ by 16 pairs,

$$\left.\begin{array}{l}\text{E}^s - \text{T}^s = 24^s\ 287\\ \text{T}' - \text{E}' = 24\ \ 581\end{array}\right\}\ \text{P} = +\ 0^s.147$$

25 Aquarii, $\delta = +1^\circ\ 31$ by 17 pairs, with another opening of the wires,

$$\left.\begin{array}{l}\text{E} - \text{T} = 20^s\ 088\\ \text{T}' - \text{E}' = 20\ \ 412\end{array}\right\}\ \text{P} = +\ 0.162$$

Another set of 14 pairs,

$$\left.\begin{array}{l}\text{E} - \text{T} = 20^s\ 053\\ \text{T}' - \text{E}' = 20\ \ 371\end{array}\right\}\ \text{P} = +\ 0.154$$

63 Aquarii, $\delta = -5^\circ\ 6'$, 16 pairs,

$$\left.\begin{array}{l}\text{E} - \text{T} = 20^s\ 100\\ \text{T}' - \text{E}' = 20\ \ 444\end{array}\right\}\ \text{P} = +\ 0.172$$

Again 15 pairs,

$$\left.\begin{array}{l}\text{E} - \text{T} = 20^s\ 207\\ \text{T}' - \text{E}' = 20\ \ 613\end{array}\right\}\ \text{P} = +\ 0.203$$

The mean of the seventy-eight pairs is $+\ 0^s.167$, or Mr. Thompson observes so much later than Mr. Edmondson. I regret that the moon was not observable. They tried the sun's second limb, and found by 14 pairs $\text{P} = +\ 0.225$.

Hence, our true difference of longitude is by

Rocket signals .	$1^m.$	$14^s.$	258
Chronometers . .		14	220

I stated that it appeared unnecessary to continue the signals at Slieve Gullion; and this, I hope, will be admitted in reference to the object proposed, the determination of the arc of longitude between Dublin and Armagh.

As, however, calculating on the number of failures in the French rockets, I had got more than proved to be required, it is my intention to employ the remainder in a way, which, while it verifies the present work, will determine the

position of another point, likely to become of great importance, the Observatory of E. J. Cooper, Esq., at Markree; which, not merely from the magnificence of its instruments, but the intention of its possessor to make it a permanent establishment, merits this distinction. It will be seen, on referring to the map, that the high mountain Cultiagh, in Leitrim, has been selected with this view: it is visible from Markree, barely hid from Armagh by Cairnmore; and, though eighty-two miles from Dublin, yet, as 1700 feet above its summit will reach the view at that place, this, also, is completely within the scope of these rockets. If there be any fine weather in autumn, I hope to perform this then; and, afterwards it will be our object to connect the Irish observatories with those of Scotland and England. Several points in Antrim are visible from Armagh, and also from the west coast of Scotland: and if the method of successive signals were employed, there is no difficulty in reaching Edinburgh. But for reasons already given, I would use this only as a last resource, and then make the intermediate stations absolute, which, if they are chosen at primary points of the triangulation, is likely to give very useful geodetic information.

But in the present instance I conceive it quite possible, by using large rockets, to effect the junction with one signal station. The mountain Goatfell, in the Island of Arran, has been chosen as the station. Its height is 2865 feet, and if the rockets can add to this 3300, they will be in view both here and at Edinburgh, the distances being 105 and 86 miles.

That this can be accomplished is certain, for a few which I made recently, no heavier than those which have been described, rose, with four ounces of powder, 4500 feet; and if the Board of Ordnance continue their powerful aid to us, I am confident of success.*

Similar rockets will, I think, also connect immediately Oxford with Dublin. If fired on Plinlimmon, 1500 feet will bring them within view of the latter, and also of the other, probably, unless the circumstances of the ground in its vicinity forbid it. But as to this I have not yet consulted my geodetic Mentor. If, however, it be necessary to observe them from one of the neighbouring hills,

* Since this was written, the Board have granted my application for a supply of rockets capable of ascending to the required height.

that is scarcely an objection, if it be so near the observatory that time can be transmitted *certainly* by powder signals, as they can be multiplied to any extent.

The junction of Oxford with Greenwich is a matter of no difficulty.

T. R. ROBINSON.

ARMAGH OBSERVATORY.